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Injury Risk for Research Subjects With Spina Bifida Occulta in a Repeated Impact Study: A Case Review

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Spina bifida occulta (SBO) occurs in 18-34% of the normal U. S. population. Recently, 16.5% of normal, asymptomatic male soldier volunteer candidates in a U.S. Army Aeromedical Research Laboratory ride motion study were excluded from the study because they had SBO at one vertebral level. Disqualifying this percentage of screened research subject candidates threatened the timely completion of the schedule intense protocol. Although one study suggests that SBO at spinal level S1 has a higher incidence of posterior disc herniation, the preponderance of clinical literature reports that spina bifida occulta is not a medical problem. The impact literature indicates that lumbosacral vertebral bodies fracture at 7.14 kN in static compression and 20 plus g during dynamic vertical impacts. In this paper, we examined the human data observed in ejection seat incidents, the rationale for excluding volunteers with single level SBO, and the path of axial load transmission through the lumbosacral spine. Based on the findings, we concluded that research volunteers with single level SBO are not at increased risk for injury, and recommended inclusion of these volunteers in future studies involving repeated axial impacts due to ride motion.

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INTRODUCTION

The nature of the various military occupational specialties dictate strict medical and physical standards. Some service members are exposed to repeated impacts with significant axial loads such as those in fast attack vehicles and high speed boats. Spinal dysraphic conditions other than spina bifida occulta (SBO) without overlying skin manifestations at one vertebral level are disqualifying for military duties (DOD Directive 6130.3). The military routinely does not screen for SBO radiographically.

Spina bifida occulta is a developmental abnormality that consists of a small interruption in continuity of the posterior arch with no neurologic deficit (15). The spinous process may be absent or is composed of two rudimentary processes from the laminae meeting, but not fused in the midline. The intervening space is occupied by a fibrous membrane. SBO, without cutaneous manifestations, is rarely associated with any clinical consequences (13). However, one study suggests that SBO at spinal level S1 has a higher incidence of posterior disc herniation (2). SBO is usually an incidental finding on radiographs of normal people (4). Single level SBO occurs commonly at spinal level S1, followed by L5, then in the cervical area (8). Surveys of normal, healthy adults show a prevalence between 18-34% (3,4,8,12,14). According to a 1946 study (7), the prevalence in the military population (mean age 26.6) is 36%.

The medical effects to single, high + Gz (axial) forces are well known in the ejection seat environment (10). However, the health and performance effects of repeated impact exposure are unknown but currently under study. A recent US Army Aeromedical Research Laboratory (USAARL) ride motion study excluded volunteer research subject candidates with SBO because of a perceived increased risk for injury. Disqualifying a significant percentage of screened research subject candidates threatened the timely completion of the schedule intense ride motion protocol. This paper examines the rationale for excluding research subject volunteers with SBO at one vertebral level and proposes a new guideline.

METHODS

Seventy nine male soldier volunteers, ages 18-40, were screened for exposure to repeated mechanical impacts up to 4 g at 5-20 Hz, and for durations up to 7 hours for one day and up to 4 hours on five consecutive days. Medical screening included a complete history, focused physical exam, and a standard anteroposterior and lateral lumbosacral series. The soldiers were disqualified from the participation in the study if their history indicated chronic symptoms, recurrent treatment, or surgical procedures for pathologic back conditions. A history of episodic mechanical low back pain was not a disqualifying criterion. They were disqualified if their physical exam revealed scoliosis, lower extremity neuropathy, cutaneous manifestations of SBO, or acute tenderness to palpation of the paravertebral musculature. Any radiographic variant or abnormality, as read by the board-certified radiologist of the adjacent accredited military medical facility, was exclusionary.

Female soldiers were not included in the protocol for two reasons. At the time the protocol was designed, female soldiers were not assigned to units that had the fast attack vehicles or high speed boats. Hence, female soldiers were not exposed to the impact forces in question. Also, choosing only male research subjects eliminated physiologic data variation between males and females.

FINDINGS

The mean age for the volunteer candidate population was 26.8. Forty-seven percent (37/79) of the male volunteer candidates were officers and 53% (42/79) were enlisted. Eighty-four percent (66/79) of the volunteer candidates were white and 16% (13/79) were nonwhite. All had a negative history of a chronic back problems and were asymptomatic for back pain.

Of the 17 medically disqualified from the protocol, one had just recovered from an acute episode of mechanical low back pain, one had spondylolysis, one had degenerative joint disease, and one had a pars defect. None of the remaining disqualified subjects had dimpling or a hairy patch over the lumbosacral spine. Thirteen had SBO at either the L5 or S1 level on radiographic examination. Table 1 compares those screened volunteers who had SBO to those who did not by age, race and rank.

Table I.
Distribution of SBO in screened asymptomatic volunteers.

		SBO	No SBO
N		13	66
AGE (mean)		27.7	26.6
RACE	Caucasian	12	54
	Noncaucasian	1	12
RANK	Officer	6	31
	Enlisted	7	35

There was no significant difference in the mean age for those who had SBO and those without SBO (T test=.7711, p=.4430). Univariate Logistic Regression model showed no association of SBO with race (Caucasian=1, OR=2.67, $CI_{0.95}$=0.316,22.5) and rank (officer=1, OR=0.968, $CI_{0.95}$=0.294,3.19).

DISCUSSION

The 16.5% prevalence of SBO in our population of male soldiers was consistent with the 23% found in the normal, asymptomatic U.S. population (6), 22% found in an emergency

department's outpatient population whose symptoms were completely unrelated (3), 15.2% found in a London historic population (13), 15.7% found in a contemporary London population (13), and 17% of a referred back pain population (2).

Based on the automotive impact literature, the compressive force required to fracture an isolated cadaver lumbar vertebra is 7.14 kN, the thoracic vertebra is 6.30 kN, and cervical vertebra is 4.09 kN (12). Assuming a 100-pound mass loads the spine (upper torso), these forces are equivalent to16.1 G, 14.2 G and 9.2 G, respectively. The high performance jet community put a 20 G exposure limit on ejection seats (5). Single impact (ejection seat) primate studies showed fractures that clustered around C7 and T10 (10) and observational human ejection seat incidents showed clustering around T12/L1 (1). This suggests that the spinal area at risk is not the lumbosacral area and that the lumbosacral area can be subjected to higher loads than the cervicothoracic areas.

In normal backs, it is unknown if a significant amount of axial loading is transmitted through the pars interarticularis at L5, or whether the vertebral centrum bears the full load (11). Symmetrically loaded primate spines showed primarily comminuted, burst vertebral centrum fractures, while asymmetric loading showed wedge fractures and significant derangements of the articular facets (10). The lumbar articular facets are nonweight bearing and their involvement in force transmission is dependent on the rotational angle of the pelvis and the resiliency of the intervertebral disks (11). In a seated individual whose pelvis is rotated forward, the path of force transmission is through the anterior elements of the lumbosacral spine as shown in figure 1.

The U.S. Air Force had significant medical concerns for those who had back conditions that were previously quiescent and did not produce sufficient symptoms until exposure to the high G environment (9). These conditions included spondylolysis, spondylolisthesis, Klippel-Feil syndrome, Scheuermann's disease, spondylolysis deformans, and vertebral body fractures. It is believed that any structure with less than optimal strength is at increased risk for injury, however, biomechanical studies have not been done to correlate vertebral column abnormalities to spinal kinematics and strength (11). In the case of SBO at one vertebral level, it is reasonable that the axial force can be transmitted through the intact ipsilateral pars interarticularis.

Some limitations remain when evaluating whether asymptomatic SBOs are at higher risk for injury than those with normal backs. The fracture loads stated are for single static compressive and dynamic vertical impacts. We do not know if there is a fatiguing cumulative effect of repeated impacts that would lower the fracture threshold.

CONCLUSION

Because the prevalance of SBO inhibited efforts to recruit research subjects, timely execution and completion of a ride motion research project was threatened. Furthermore, conclusions [results] from the ride motion study may not be valid because a representative military population was not chosen. Given the vertebral fracture load forces, spinal level at risk, path of force transmission, clinical insignificance of SBO, and low level G exposure of repeated impacts in surface ride motion,

we do not feel that normal, asymptomatic research volunteers with SBO at one vertebral level and no cutaneous manifestations, are at increased risk for personal injury. We recommend that others designing similar studies consider including these research candidates.

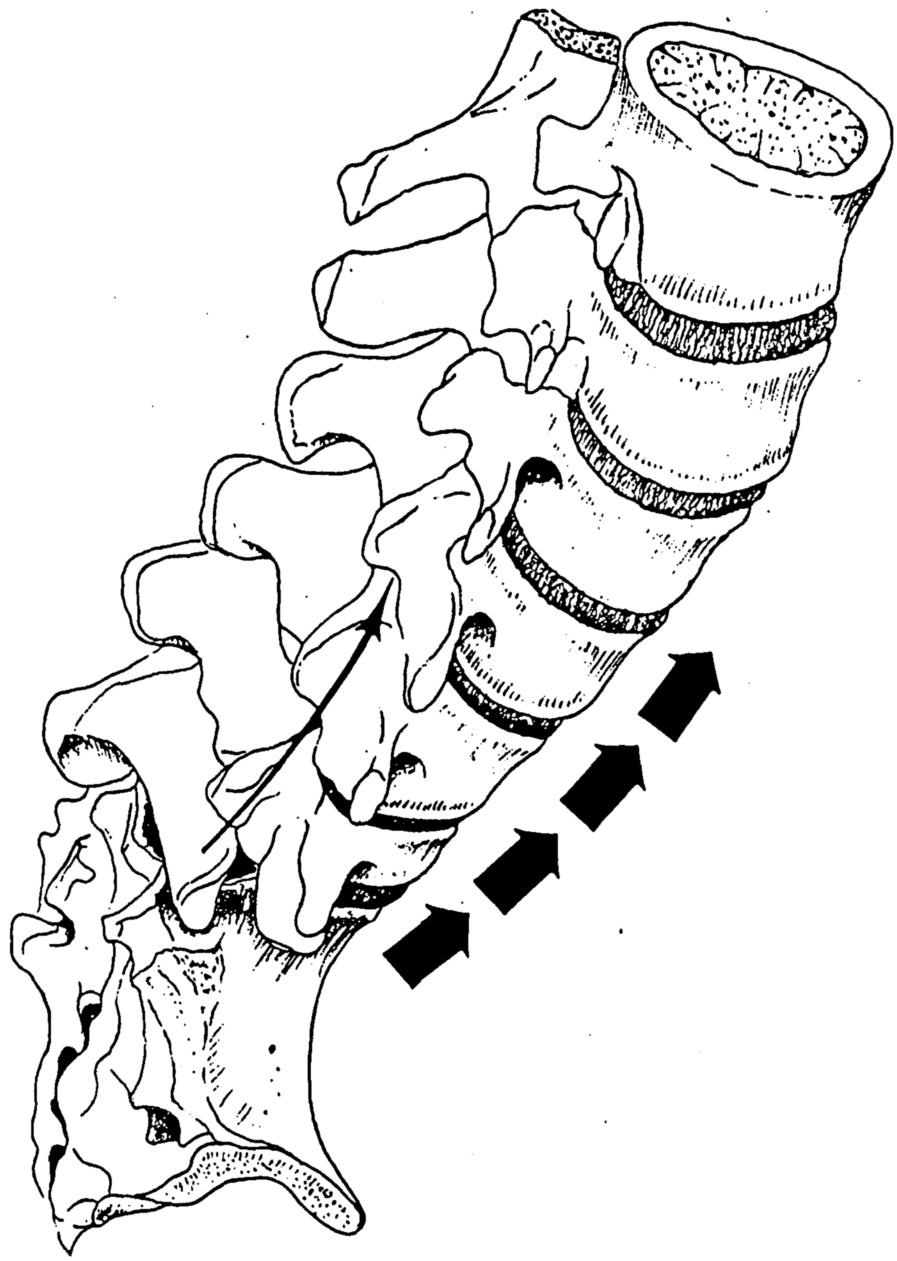

Figure 1. Path of axial load transmission primarily through the anterior element with minimal transmission through the pars interarticularis in a normal lumbosacral spine. SBO at L5 or S1 would not affect the ipsilateral transmission through the pars interarticularis.

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